my adventure exploring the smallest intervals of space and time and preparing to explain it to high school students

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Tuesday, 26 July 2011

The Holographic Principle

- theory proposed by Craig Hogan
- the reality that we perceive is actually a three-dimension projection from the two-dimensional reality at the edge of the universe

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That sounds pretty cool...
... like science fiction

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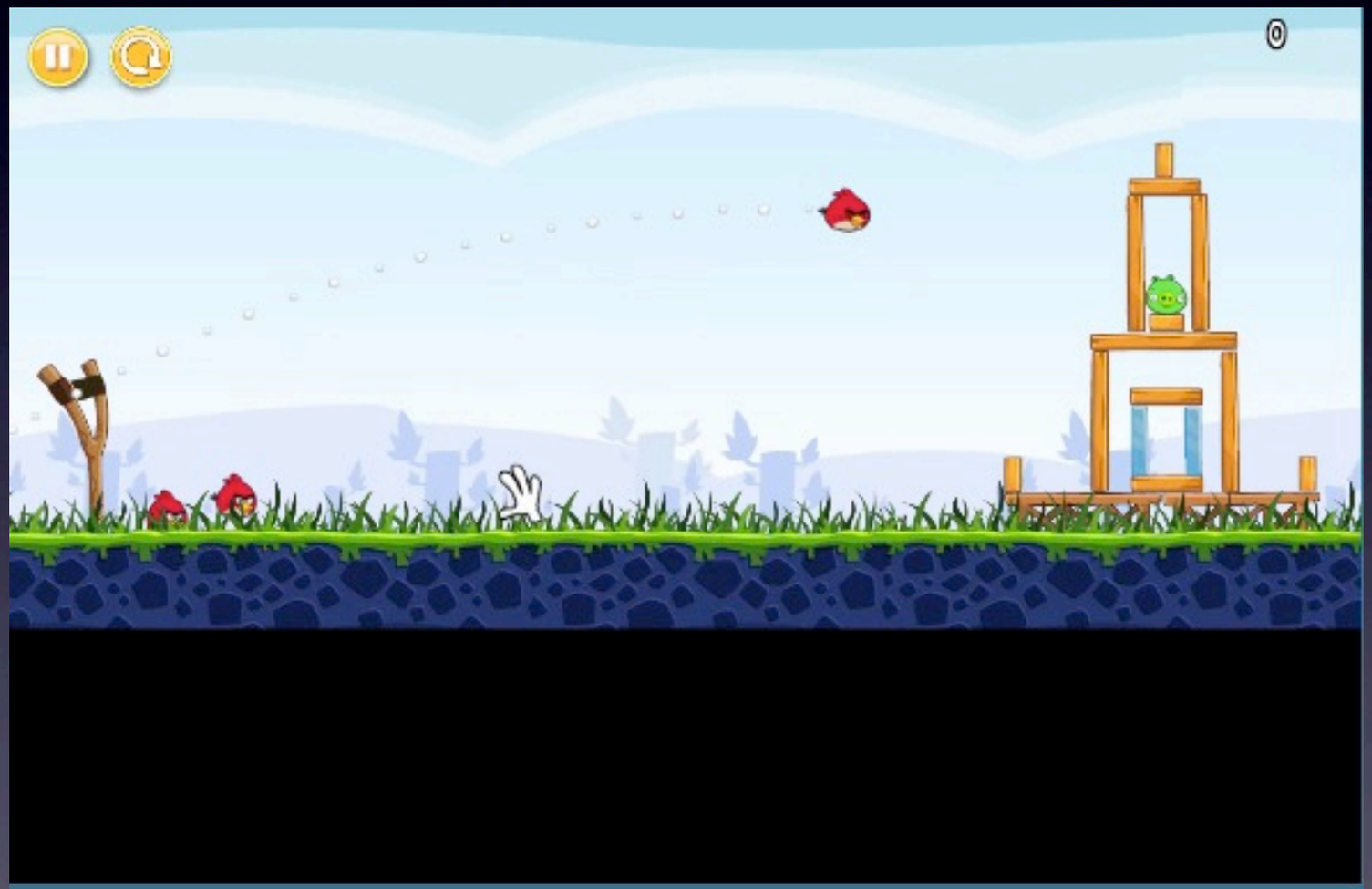
... like science fiction

Wait, what does that mean?

Angry Birds



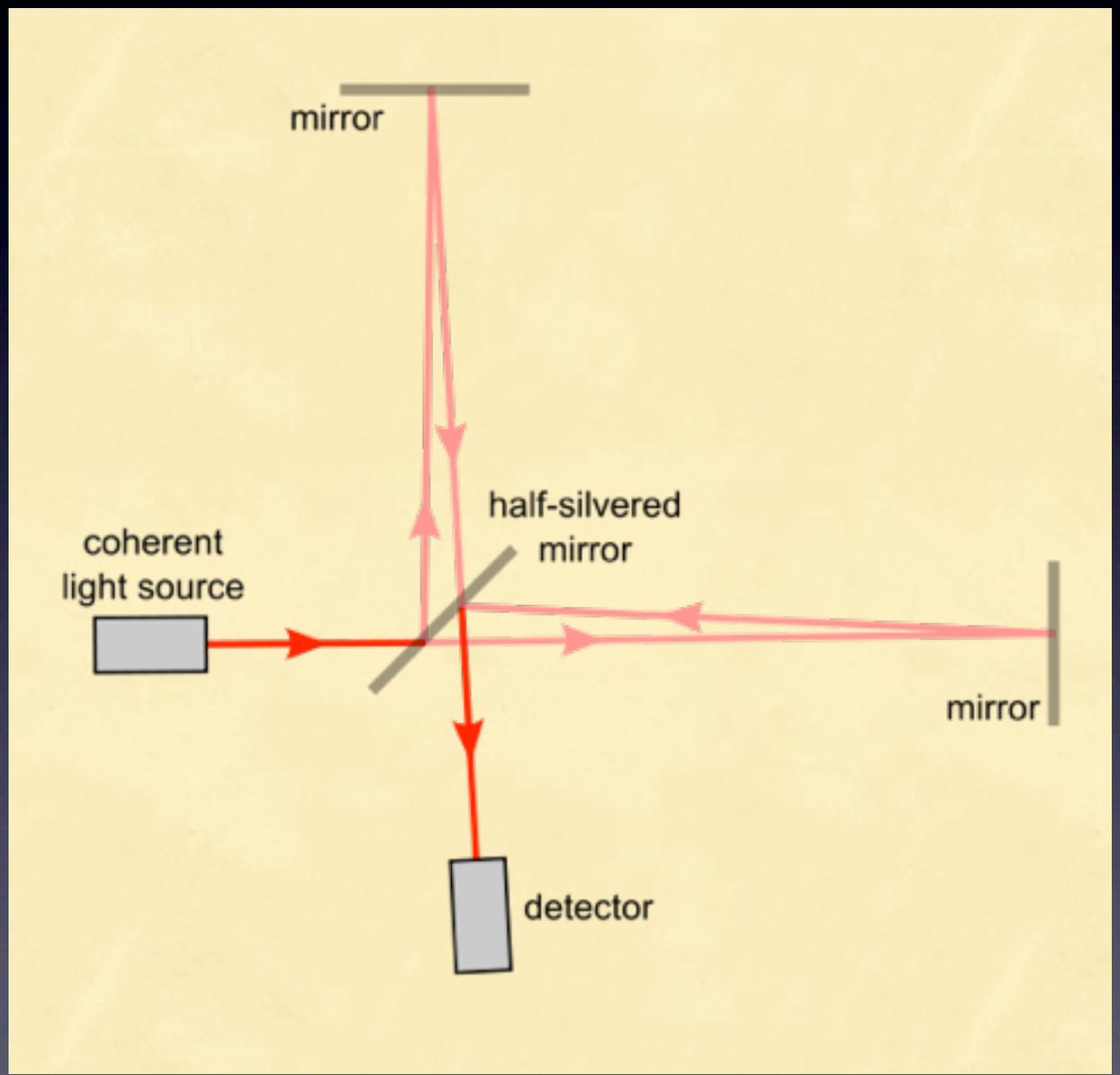
Look Closer

Holographic Noise

- as we move through space time, we experience a jitter on the scale of Planck's length
- 1.6×10^{-35} m (that's very small)

The Most Sensitive Instrument

- the interferometer
- designed by Albert Michelson
- detects small differences in distance (or time) via interference patterns
- on the order of fractions of the wavelength of light

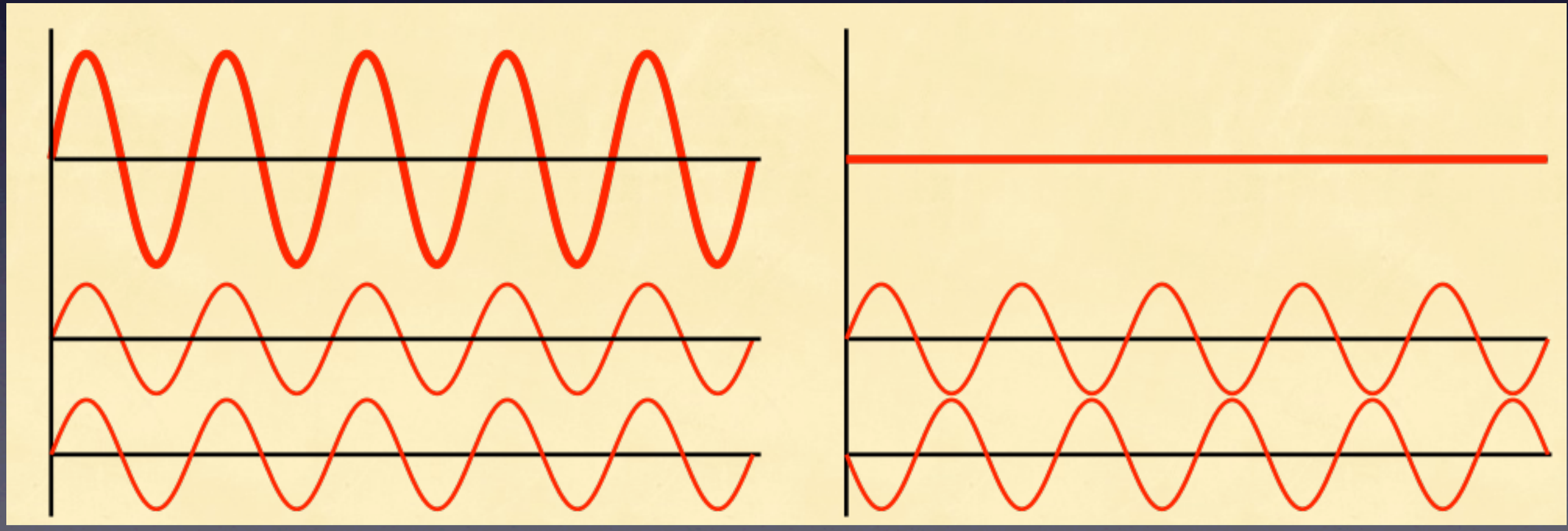


source: wikipedia

Interference

constructive

destructive



source: wikipedia

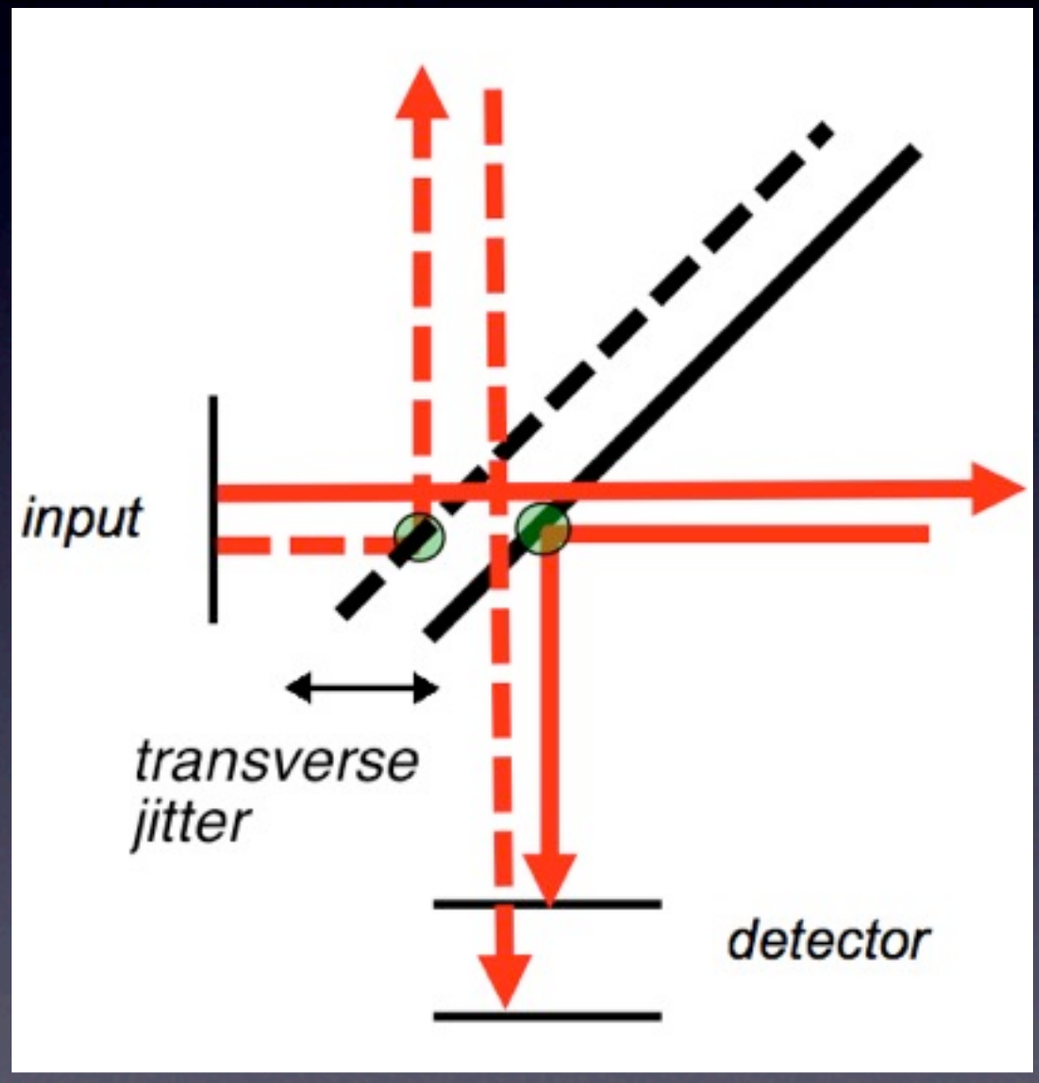

PURPLE NITRILE
LCWR


EMERGENCY
EXIT
Interlocks will disable laser
when door is opened
DANGER
INVISIBLE LASER RADIATION
AVOID EYE OR SKIN EXPOSURE
TO DIRECT OR SCATTERED RADIATION
EYE PROTECTION REQUIRED
FOR UNENCLOSED OPERATION
ND:YAG INFRARED 2.1 W CLASS 4

The Planck Length Is a Bit Smaller Than the Wavelength of Light...

Planckian Physics

- measuring position in perpendicular directions results in uncertainty
- that is, precisely measuring position in one direction results in transverse jitter in the other
- that is our holographic noise



source: Craig Hogan

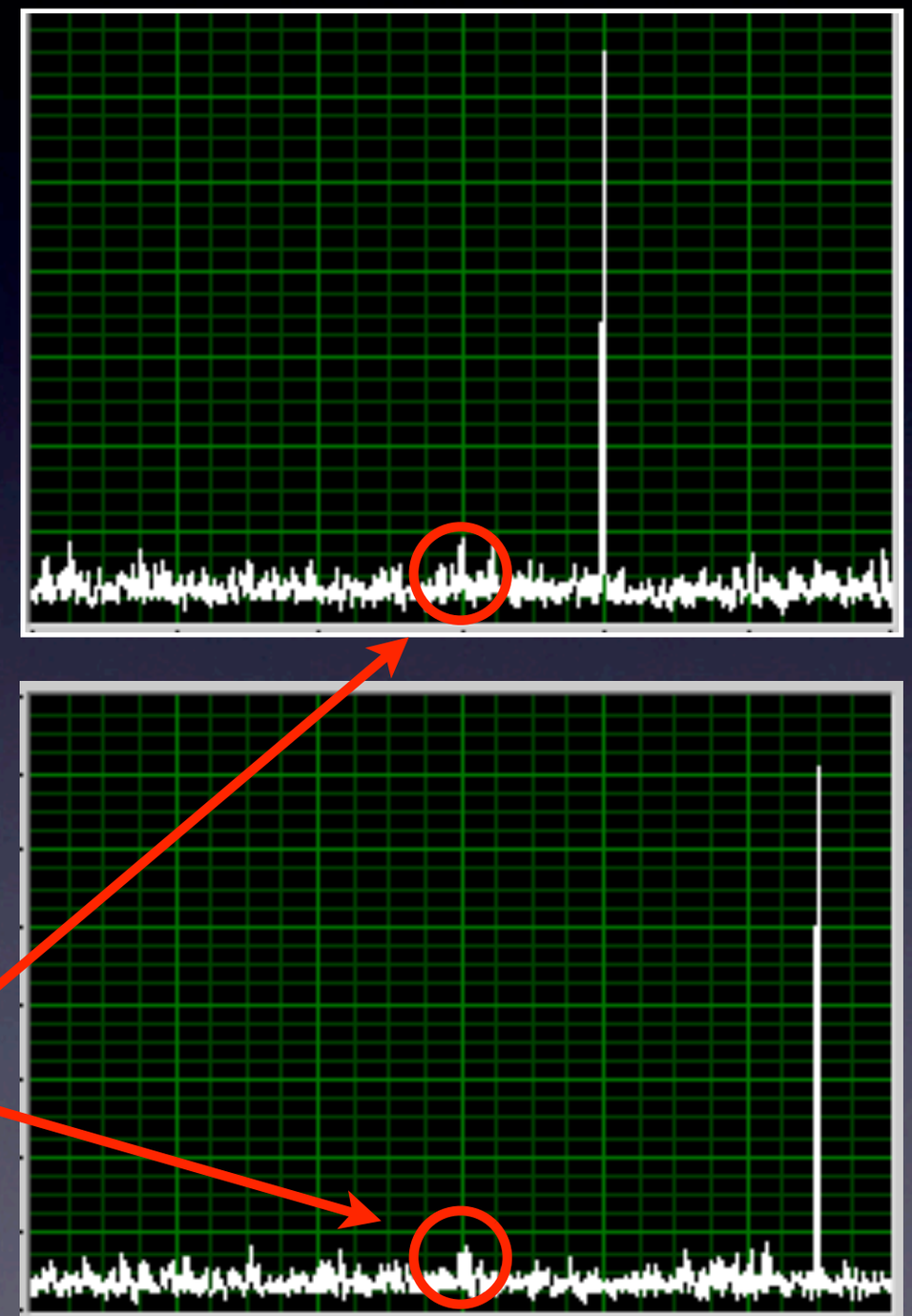
How Much Jitter?

- beam splitter can move 1 Planck length for every Planck time that the photon travels the arm
- random walk on the order of 10^{-17} m
- that's still pretty small

Clever Spectral Analysis

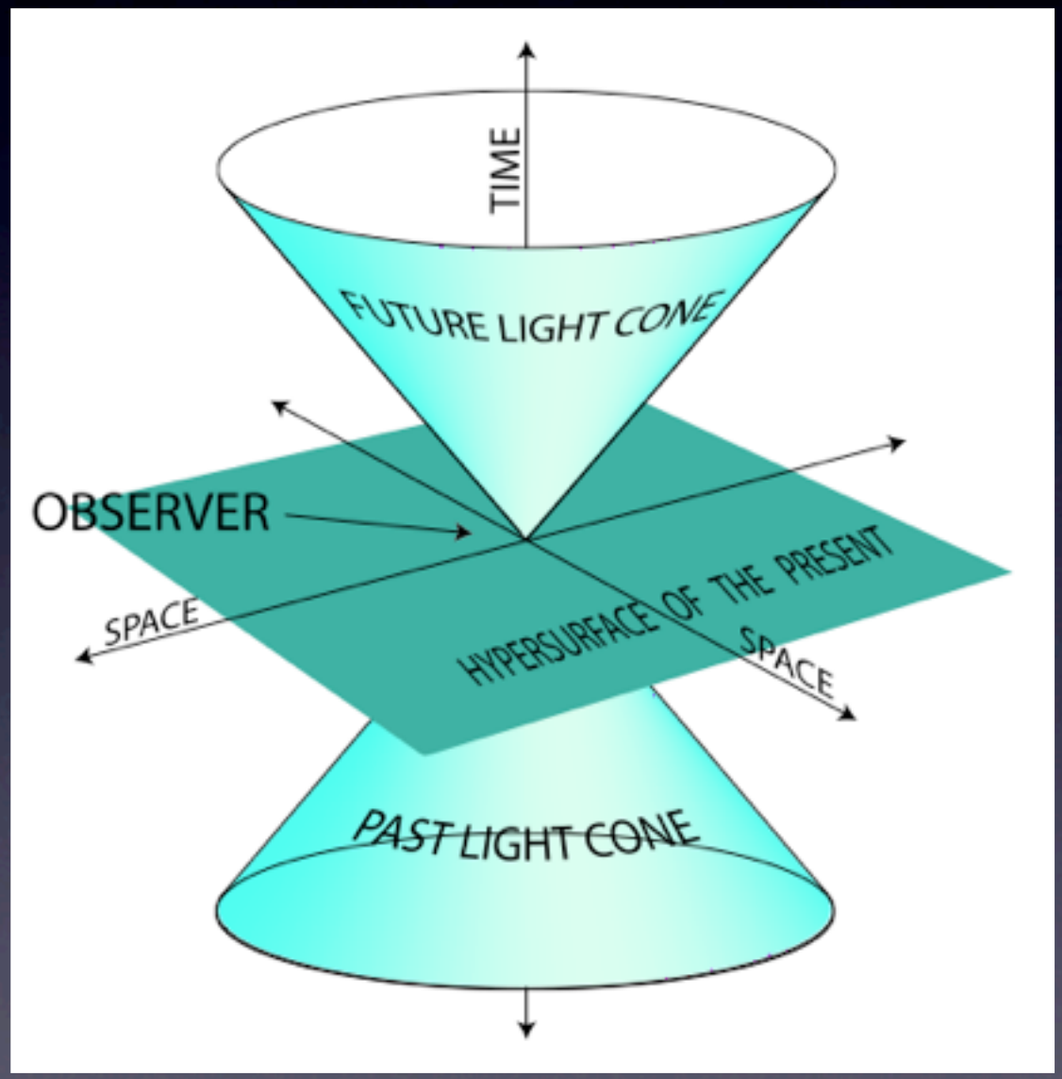
- analyze signal from the photodiode in the frequency domain
- just looks like noise to me

holographic noise



Light Cone

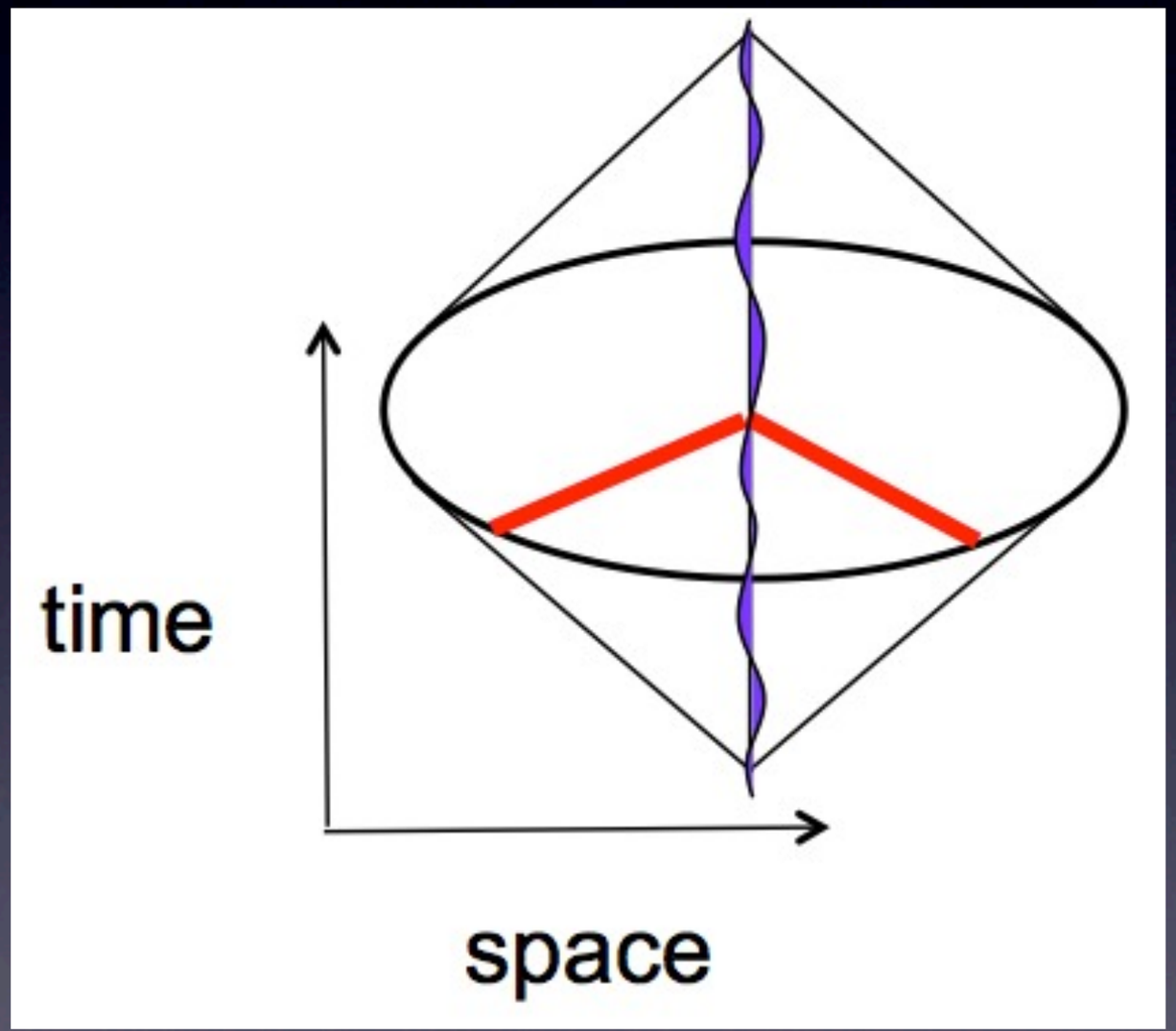
- illustrates three dimensions (2 spacial; 1 time)
- for a given event, shows the space-time that could have affected that event and the effect of that event on future events
- causality!



source: wikipedia

Interferometer Causal Diamond

- top half:
  - past light cone of the beamsplitter reflection
- bottom half:
  - future light cone of another beam splitter reflection
- diamond:
  - intersection of the cones

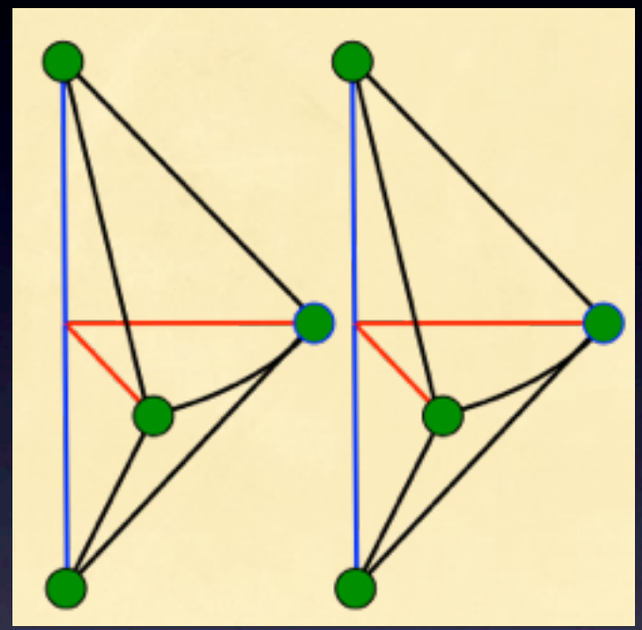


source: Craig Hogan

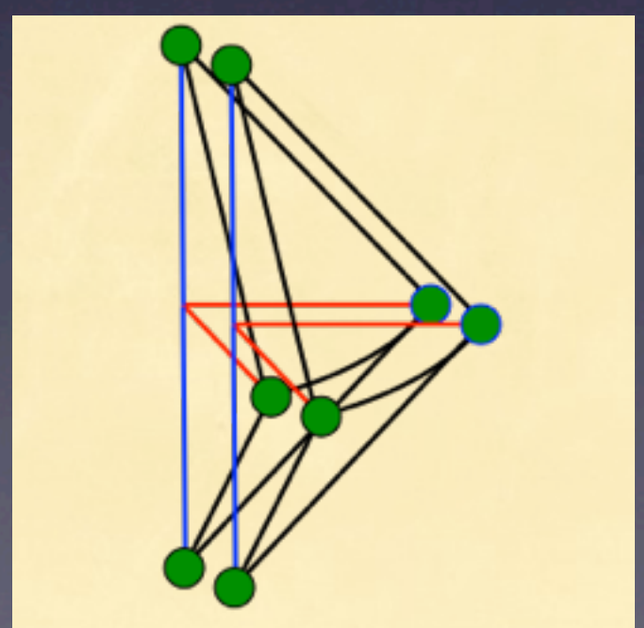
for future civilizations

Correlated Holographic Noise

- holographic noise is correlated for overlapping causal diamonds

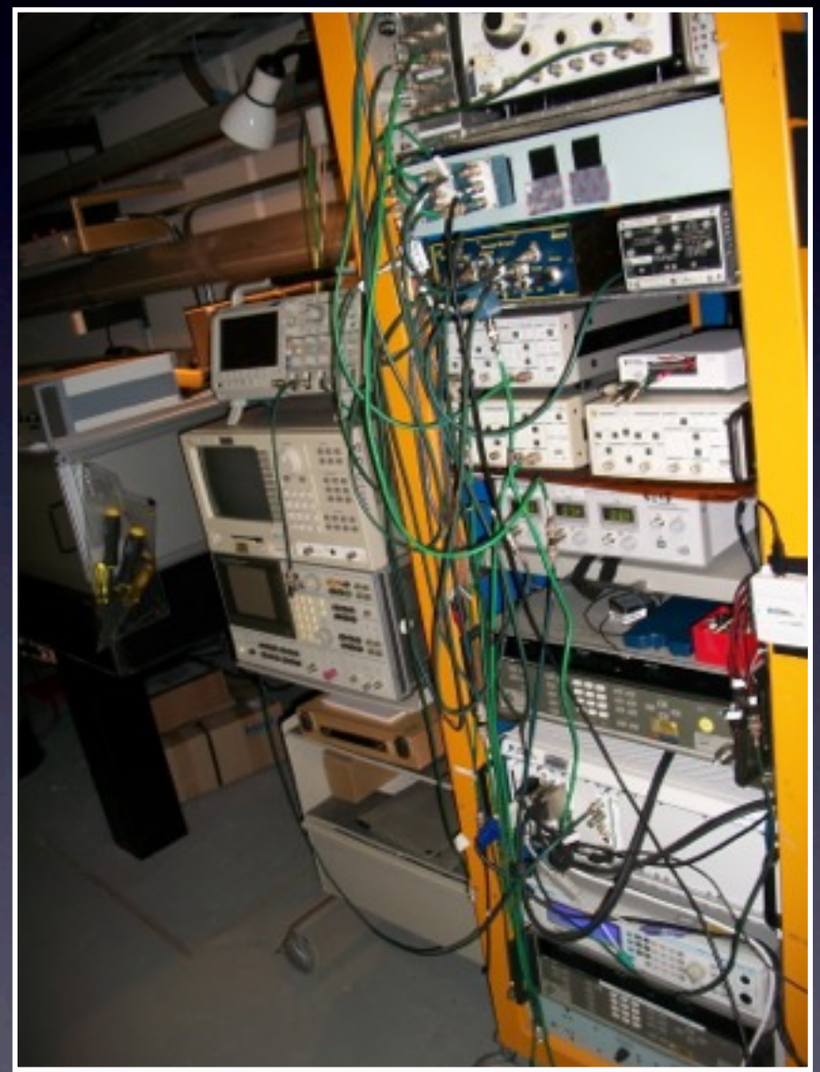


- holographic noise is uncorrelated for non-overlapping causal diamonds



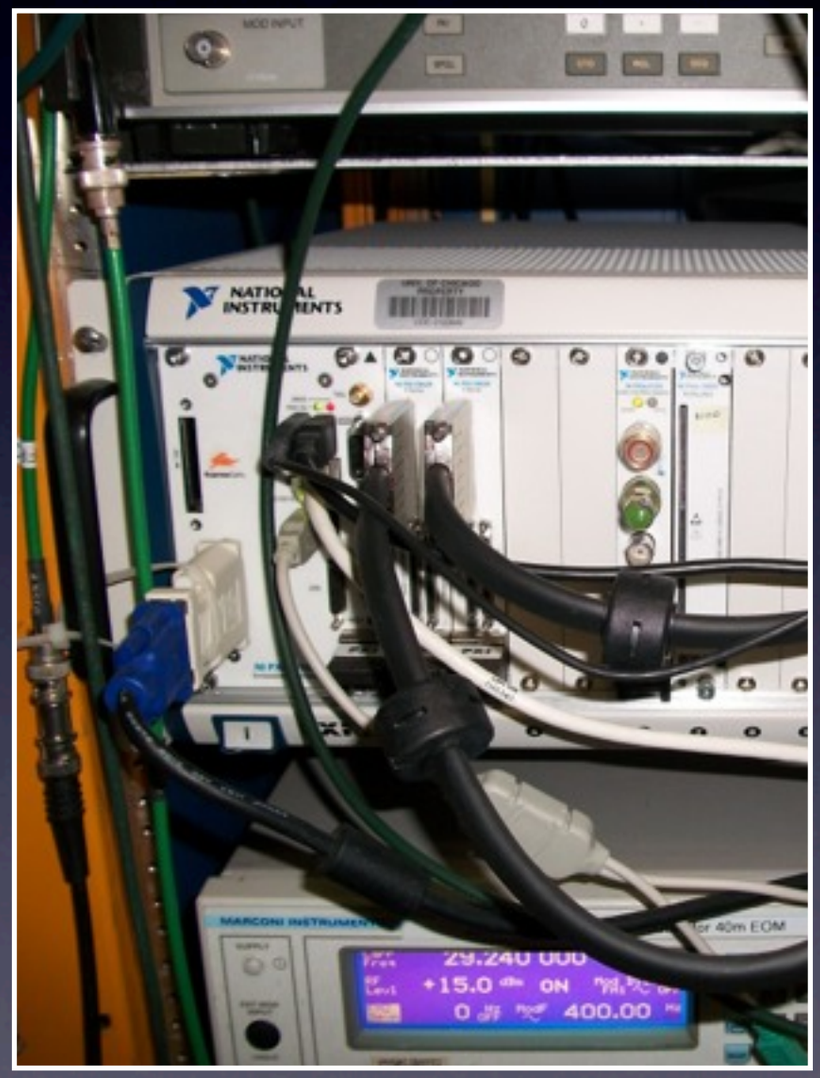
Measurements Requirements

- digitize two analog signals at 50 MS/s
- stream all data to disk for offline analysis (200 MB/s)
- perform spectral analysis in real-time for experiment tuning (this is the kicker)



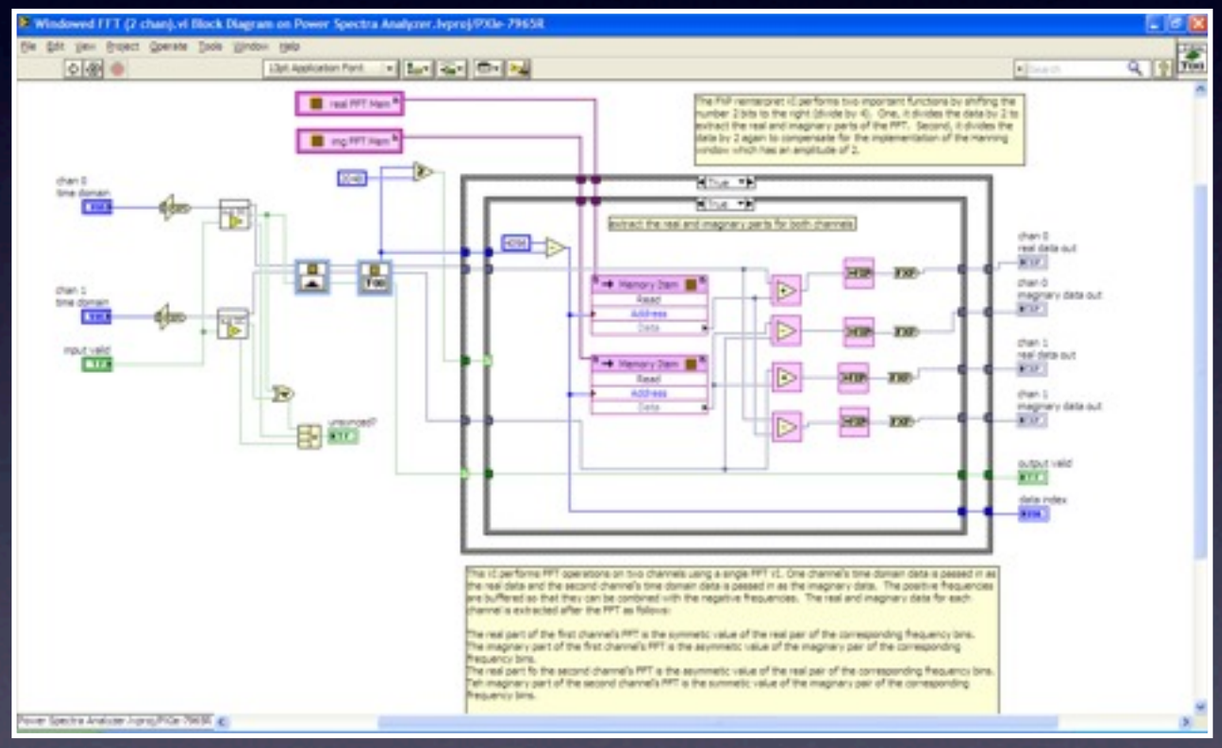
Computer-Based Measurements System

- PXIe chassis (4 GB/s system bandwidth)
- PXIe controller (1.73 GHz quad-core Intel Core i7-820 processor)
- 2 channel, 100 MS/s, 14-bit digitizer
- FlexRIO FPGA device
- 12-drive RAID array (750 MB/s)
- LabVIEW and FPGA Toolkit



Computer-Based Measurements Solution

- stream data from digitizer to FPGA and controller and RAID at 200 MB/s
- perform spectral analysis in real-time on FPGA and streaming to controller
- amazing that this can be done with off-the-shelf hardware by a high school teacher in six weeks



Many Thanks...

- Fermilab TRAC Program – amazing opportunity
- Chris Stoughton – excellent mentor; archetype of “getting stuff done”
- Craig Hogan – patient with my questions and generous with his time
- National Instruments – lending me expensive hardware for the summer

Want More Details?

- Holometer series at pedagoguepadawan.net